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Adult macronutrient intake and physical capability in the MRC National Survey of Health and Development

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Abstract

Background: poor physical capability is associated with higher subsequent risk of disability and mortality in older people. Energy and macronutrient intakes may play a role in the maintenance of physical capability. This analysis aimed to examine the role of intakes of energy and the macronutrients, protein, carbohydrate and fat in early and mid-adulthood on objective measures of physical capability in later adulthood in the MRC National Survey of Health and Development (1946 British birth cohort).

Methods: adult diet assessed by a 5-day diary at 36 years (1982) and 43 years (1989). Physical capability was assessed at 53 years. Objective measures were height, weight and three measures of physical capability: grip strength, standing balance time and chair rises.

Results: using multiple linear regression analysis, modest positive associations were found between energy intake at 36 and 43 years and grip strength at 53 years. Results for macronutrients were mixed although there was some indication of relationships of protein intake with grip strength and standing balance time.

Conclusions: higher energy intake in midlife may play a role in the prevention of muscle weakness in later life. Higher protein intakes may also be related to physical capability but further research is needed.

Keywords: *physical capability, diet, energy, macronutrients, longitudinal*

Introduction

Poor physical capability is associated with higher risk of morbidity and higher rates of mortality in older people [1, 2]. Muscle strength and muscle mass decline with age, reflected in common measures of physical performance such as grip strength, chair rises and standing balance [3]. A number of modifiable factors, including diet, may impact on muscle mass and function and on physical performance. However, the dietary components that influence muscle mass and function remain elusive, with conflicting results in the literature [4, 5].

Since muscle contains over 80% of protein-bound amino acid in the body, protein intake is often hypothesised to have the greatest impact on muscle mass and function. Adequate dietary protein is a prerequisite for muscle protein synthesis [6] and decreased protein intake results in reduced muscle mass in older people [7]. However, administration of additional protein in older people shows conflicting results [7]. In population studies, protein intake has been associated with muscle mass and the rate of muscle loss [8, 9] and positively associated with grip strength in older women [5]. In the Women's Health Initiative Observational Study, higher protein intake was associated with a strong, dose responsive, lower risk of frailty after 3 years of follow-up [10].

Carbohydrate and fat intakes may also impact on skeletal muscle through effects on glucose transport, glycogen synthesis and glucose oxidation, processes which can deteriorate with age and result in insulin resistance or insensitivity [11]. Insulin concentrations, the metabolic syndrome and type 2 diabetes have been associated inversely with grip strength [12, 13], relationships which may be mediated by diet. Skeletal muscle also accounts for substantial fatty acid oxidation in the body, and diminished fatty acid oxidation is associated with glucose intolerance [14].

Although muscle mass declines with inadequate energy intake [15, 16], there is little work examining the impact of total energy intake in population-based studies. Most investigations have assessed diet using food frequency questionnaires where the validity of total energy intake estimates are questioned [17]. This study aims to examine the effects of energy and macronutrient intakes assessed through detailed diet diaries at two time points in adulthood with three objective measures of physical capability measured in later adulthood, using the MRC National Survey of Health and Development (NSHD).

Subjects and methods

Study population

NSHD is a longitudinal study of a socially stratified sample of all births during 1 week in March 1946 in England, Wales and Scotland. The sampling procedure and follow-up are described in more detail elsewhere [18]. In spite of attrition through death, living abroad, permanent refusal, temporary refusal for specific time points and some untraceable cases, the sample in 1999 at 53 years was still representative of the UK population in most respects [18]. Physical capability measures were available at 53 years only. After exclusion of participants with incomplete data on confounders, the numbers available for inclusion in analyses of diet and grip strength, standing balance time and chair rise time was 1,771, 1,741 and 1,713, respectively, for dietary data for 36 years and 1,717, 1,688 and 1,675, respectively, for dietary data for 43 years.

Ethical approval for the assessment of the NSHD cohort was obtained from the Bristol & Weston Health District for the 1982 assessment, from the Joint UCL/UCLH Committee on the Ethics of Human Research for 1989 and from the North Thames Multi-Centre Research Ethics Committee for the 1999 assessment.

Physical capability assessment

Physical capability was measured at 53 years using grip strength, chair rise time and standing balance. Trained nurses conducted the tests during home visits using standardised protocols described elsewhere [19]. Grip strength (in kilogram) was measured isometrically using an electronic handgrip dynamometer. Two values were recorded for each hand and the highest used in analyses. Standing balance time was measured as the longest time, to a maximum of 30 s, for which participants could maintain a one-legged stance in a standard position with eyes closed; values were logged to normalise the distribution. Chair rise time was measured as the time taken to rise from a sitting to standing position with straight back and legs and then sit down again 10 complete times. For high scores to indicate good performance, the reciprocal of the time taken (multiplied by 100) was used.

Dietary assessment

Dietary intakes were obtained using 5-day estimated (unweighed) diaries in 1982 and 1989 when participants were 36 and 43 years. All food and drink consumed was recorded using household measures and estimating portion sizes using detailed guidance notes. In 1982, dietary information was converted into food codes and weights manually before being converted into electronic form for calculating intakes. In 1989, the diary included photographs to assist portion size estimations; coding was carried out by the Dunn Nutrition Unit, Cambridge using an in-house computerised data entry programme DIDO [20]. The 1982 manually coded data were later converted with the in-house analysis programmes of MRC Human Nutrition Research, Cambridge [20]. Food and nutrient intakes for both time points were calculated based on McCance and Widdowson's 'The Composition of Foods, fourth edition and supplements' [20].

Potential covariates and confounders

Height (in metre) and weight (in kilogram) at 53 years, measured by nurses using standardized protocols, were adjusted for in all analyses as these have been associated with all three measures of physical capability [19]. Childhood social class, adult social class and education were also adjusted for as they are associated with both physical capability and dietary intake [19]. Childhood social class was based on father's occupation when participants were aged 4 years. Adult social class was based on occupational class at 53 years (or at 43 years if missing at 53 years, or at 36 years if missing at 53 and 43 years). Both occupational class measures were categorised into four groups (professional and intermediate (I and II), skilled non-manual (IIINM), skilled manual (IIIM) and partly skilled and unskilled (IV and V)). Education level at 26 years was categorised into advanced degree, advanced secondary qualifications, ordinary secondary and no formal qualification.

Physical activity was added to the model where positive associations were found in the fully adjusted model, to test whether physical activity mediated the relationships. At 36 and 43 years, participation in sports and recreational activities were assessed by self-report [21]. Both activity variables were categorised into three groups, as in previous analyses [22], to ensure their comparability: inactive, moderately active and most active.

Statistical analysis

Multiple linear regression was used to model the relationships of energy, protein, carbohydrate and fat intakes with grip strength, chair rise time and standing balance time. Tests for sex interactions were performed and where there was evidence of this in the unadjusted model; all subsequent analyses were carried out separately for men and women. The initial model included macronutrient or energy intake, the physical capability measure, height and weight; energy intake was then added for the macronutrients, as well as childhood social class, adult social class and education. The final model included all covariates. Sex interaction terms were included for height and weight since effects of height and weight on the physical capability measures differ by sex [19].

Results

Sample characteristics

Macronutrient intakes as a percentage of total energy intakes were comparable at both time points (Table 1). Mean carbohydrate intake was lower than the dietary reference value (DRV) of 47% total energy [23] and mean fat intake was higher than the DRV of 33% total energy at both ages. Energy intakes were in line with the DRV; they were slightly lower at 36 years compared with 43 years.

Dietary intakes and physical capability measures

Tables 2 and 3 show the multivariate associations between intakes of energy and macronutrients and physical capability measures for men and women.

Table 1. Subject characteristics [mean (standard deviation)] (for sample used in analyses)

	Men	Women
Age 36 years[a]	*n* = 867	*n* = 904
Energy intake (kJ)	10,096 (2,485)	7,159 (1,980)
Energy intake (kcal)	2,410 (594)	1,707 (472)
Fat intake (g)	103 (30)	77 (25)
Carbohydrate intake (g)	263 (75)	191 (64)
Total protein (g)	84 (19)	64 (15)
Fat % energy	38.3 (5.1)	40.0 (5.2)
Carbohydrate % energy	41.7 (5.7)	42.3 (6.4)
Protein % energy	14.4 (2.4)	15.7 (3.6)
Age 43 years[a]	*n* = 877	*n* = 929
Energy intake (kJ)	10,467 (2,502)	7,782 (1,993)
Energy intake (kcal)	2,499 (598)	1,856 (476)
Fat intake (g)	108 (32)	82 (26)
Carbohydrate intake (g)	267 (73)	208 (60)
Total protein (g)	88 (21)	70 (16)
Fat % energy	38.6 (5.6)	39.2 (5.7)
Carbohydrate % energy	40.9 (6.1)	42.9 (6.1)
Protein % energy	14.6 (2.3)	15.5 (3.0)
Physical capability at age 53 for those with diet data at age 43[a]		
	n = 877	*n* = 929
Grip strength (kg)	47.4 (12.2) [*n* = 853]	28.1 (7.8) [*n* = 891]
Standing balance time (ln(s))	1.7 (0.8)	1.5 (0.8)
Chair rise time ($1/s^a 100$)	5.3 (1.8) [*n* = 837]	5.0 (1.6) [*n* = 888]
Weight at 53 years (kg)	82.8 (12.9)	70.4 (13.4)
Height at 53 years (cm)	174.0 (6.5)	161.9 (5.8)

[a]Maximum *n* for sample used in analyses.

Table 2. Associations between macronutrient intakes at ages 36 and 43 years and grip strength at age 53 years

Year (age) of dietary assessment	1982 (36 years) (n = 1,771)		1989 (43 years) (n = 1,717)	
Dietary factor:	Beta coefficient[a] (95% CI)	p	Beta coefficient[a] (95% CI)	p
Protein				
Adjusted model[b]	0.53 (0.06, 1.00)	0.03	0.51 (0.02, 0.99)	0.04
Fully adjusted model[c]	0.06 (−0.64, 0.76)	0.87	0.01 (−0.74, 0.76)	0.98
Fat				
Adjusted model[b]	0.65 (0.18, 1.12)	0.007	0.42 (−0.07, 0.92)	0.09
Fully adjusted model[c]	0.17 (−0.87, 1.20)	0.75	−0.55 (−1.62, 0.51)	0.31
Carbohydrate				
Adjusted model[b]	0.36 (−0.12, 0.84)	0.14	0.49 (−0.01, 0.98)	0.053
Fully adjusted model[c]	−1.14 (−2.12, −0.17)	0.02	−0.30 (−1.23, 0.63)	0.53
Energy				
Adjusted model[b]	0.67 (0.19, 1.15)	0.007	0.63 (0.14, 1.13)	0.01
Fully adjusted model[c]	0.61 (0.12, 1.09)	0.01	0.58 (0.08, 1.07)	0.02

[a]Beta coefficients represent the change in grip strength (kg) per one SD change in absolute intake of the specified dietary factor.
[b]Adjusted for sex, height, weight and interaction terms between sex and height and sex and weight.
[c]Adjusted for sex, height, weight energy intake (except in the model where energy intake is the main explanatory factor), childhood social class, adult social class, education and interaction terms between sex and height and sex and weight.

Grip strength

Positive associations were found between energy intake at 36 and 43 years and grip strength at 53 years (Table 2); these remained after adjustment for all confounders, and after further adjustment for physical activity (results not shown). In the initial model, there were positive associations between protein intake at both ages and grip strength at 53 years, but these were attenuated after adjustment for energy intake. There was a positive association between fat intake at 36 years and grip strength but this was also attenuated after adjustment for energy intake. There was no association between carbohydrate intake at 36 years and grip strength in the initial model; however, when energy was added, a negative association was seen. Conversely, a positive association between carbohydrate intake at 43 years and grip strength found in initial models was attenuated after adjustment for energy intake. There were associations between both fat and carbohydrate as % energy at 36 years and grip strength; these associations remained after adjustment for confounders (results not shown).

Standing balance time

Energy intake at 36 years was associated with standing balance time in women but was attenuated when education was added to the model. The same trend was seen for men at 36 years and for both men and women at 43 years (Table 3). There was no association in the initial model between protein intake at 36 years and standing balance time in men, but an indication of a positive association when energy intake was included. A positive association between protein intake at 36 years and standing balance time was seen for women and remained after adjustment for energy intake but was not significant at the 5% level when adjusted for childhood social class. There was also an association between protein intake at 43 years and standing balance time in women but this was attenuated when adjusted for energy intake. Protein as % energy at 36 years was related to standing balance time and remained after adjustment for confounders. There was an association between fat intake at 36 years and standing balance time in men but this was attenuated after adjustment for energy intake. Carbohydrate intake at 43 years was positively associated with standing balance time in the unadjusted model but was attenuated when childhood social class was added to the model, and carbohydrate as % energy was associated with standing balance time in the initial model at both time points, but attenuated at 36 years when adult social class was added and at 43 years when childhood social class was added (results not shown).

Chair rise time

Carbohydrate intake at 43 years was associated with chair rise time in the fully adjusted model. Carbohydrate as % energy at 36 years showed the same relationship with chair rise time. No other associations between energy or macronutrients and chair rise time were seen (Table 3).

Discussion

There is limited research on the relationship between dietary intakes and physical capability, despite the fact that nutritional factors are potentially important and modifiable. Most analyses are cross-sectional and on subjects who are already old; hence, reverse causality cannot be excluded. The current analysis was carried out to determine any associations between intake of energy and macronutrients in early and mid-adulthood and subsequent physical capability, as characterised by grip strength, standing balance time and chair rise time. Higher energy intake was associated at both ages with stronger grip strength at 53 years even when all

Table 3. Associations between macronutrient intakes at ages 36 and 43 years and standing balance time and chair rise time at age 53 years

Year (age) of dietary assessment	1982 (36 years)		1989 (43 years)	
Standing balance time	Beta coefficient[a] (n = 1,741[b])	P	Beta coefficient[a] (n = 1,688[b])	P
Protein				
	Men		Men	
Adjusted model[c]	−0.0007 (−0.06, 0.06)	0.98	0.01 (−0.05, 0.07)	0.69
Fully adjusted model[d]	0.09 (0.001, 0.19)	0.047	0.05 (−0.04, 0.15)	0.24
	Women		Women	
Adjusted model[c]	0.08 (0.03, 0.13)	0.001	0.07 (0.02, 0.12)	0.01
Fully adjusted model[d]	0.07 (−0.002, 0.14)	0.059	0.04 (−0.03,0.12)	0.29
Fat				
	Men		Both sexes	
Adjusted model[c]	−0.06 (−0.12, −0.002)	0.04	0.02 (−0.02, 0.05)	0.43
Fully adjusted model[d]	−0.08 (−0.20, 0.04)	0.22	−0.05 (−0.14, 0.03)	0.19
	Women			
Adjusted model[c]	0.05 (0.003, 0.10)	0.04		
Fully adjusted model[d]	0.01 (−0.11, 0.13)	0.87		
Carbohydrate				
Adjusted model[c]	−0.01 (−0.05, 0.02)	0.46	0.05 (0.01, 0.09)	0.02
Fully adjusted model[d]	−0.02 (−0.10, 0.06)	0.65	0.06 (−0.01, 0.13)	0.11
Energy				
	Men		Both sexes	
Adjusted model[c]	−0.05 (−0.11, 0.01)	0.08	0.04 (−0.004, 0.07)	0.08
Fully adjusted model[d]	−0.04 (−0.10, 0.02)	0.18	0.04 (−0.002, 0.07)	0.07
	Women			
Adjusted model[c]	0.05 (0.003, 0.10)	0.04		
Fully adjusted model[d]	0.04 (−0.005, 0.09)	0.08		
Chair rise time	(n = 1,713)		(n = 1,675)	
Protein				
Adjusted model[c]	−0.01 (−0.09, 0.07)	0.78	0.05 (−0.04, 0.13)	0.28
Fully adjusted model[d]	−0.01 (−0.13, 0.11)	0.87	0.09 (−0.04, 0.22)	0.17
Fat				
Adjusted model[c]	−0.03 (−0.11, 0.05)	0.51	0.02 (−0.07, 0.10)	0.67
Fully adjusted model[d]	−0.06 (−0.23, 0.12)	0.53	0.02 (−0.16, 0.20)	0.87
Carbohydrate				
Adjusted model[c]	−0.04 (−0.12, 0.04)	0.32	−0.04 (−0.12, 0.05)	0.40
Fully adjusted model[d]	−0.05 (−0.21, 0.12)	0.58	−0.19 (−0.34, −0.03)	0.02
Energy				
Adjusted model[c]	−0.03 (−0.11, 0.06)	0.52	0.02 (−0.07, 0.10)	0.70
Fully adjusted model[d]	−0.02 (−0.11, 0.06)	0.60	0.01 (−0.07, 0.10)	0.74

Note: Results are stratified by sex where there was evidence (i.e. $P < 0.01$) of interaction between sex and the specified macronutrient. Unless otherwise indicated results presented are based on models which include both men and women.

[a]850 men and 891 women for analyses of dietary factors at age 36y and 825 men and 863 women for analyses of dietary factors at age 43 years.

[b]Beta coefficients represent the change in standing balance time (ln(s)) or chair rise time (1/s × 100) per one SD change in absolute intake of the specified dietary factor.

[c]Adjusted for sex (where appropriate), height, weight and, unless models are stratified by sex, interaction terms between sex and height and sex and weight.

[d]Adjusted for sex (where appropriate), height, weight, energy intake (except in the model where energy intake is the main explanatory factor), childhood social class, adult social class, education and, unless models are stratified by sex, interaction terms between sex and height and sex and weight.

confounders were taken into account. There were also modest associations between higher protein intake at both ages and stronger grip strength when intake was expressed in absolute terms in g/d, but these were attenuated when energy intake was taken into account. There were no clear and consistent relationships between energy and macronutrient intakes at 36 or 43 years and standing balance or chair rise time at 53 years with the exception of evidence of small positive associations between protein intake at 36 years and standing balance time in both sexes in the fully adjusted models.

These analyses show different results for the three different measures of physical capability and may reflect varying lifetime influences on these indicators. The findings for grip strength were the most convincing. Grip strength has differed from the other measures of physical capability in other analyses using NSHD [19, 24]. Compared with grip strength, chair rises and standing balance require good balance and motor control, and greater concentration as well as the muscle strength required by all the measures. The role of diet may therefore be more complex and not limited to the macronutrients measured here. A number of vitamins were found to be associated with frailty in older people in the InCHIANTI study [25], and several minerals were related to muscle mass in the Tasmanian Older Adult Cohort [8]. In the Hertfordshire cohort study, grip strength was related to fatty fish intake. Examination of further dietary components is therefore justified.

The association between energy intake at 36 and 43 years and grip strength at 53 years remained after including physical activity in the model. This is consistent with the lack of association in this study between self-reported physical activity across adulthood and grip strength at 53 years [22]. There is little observational research on energy intake in relation to physical capability, possibly because food frequency questionnaires are the dietary assessment method most often used, and these are more designed to rank individuals rather than to measure total intake [26, 27]. In this analysis, use of dietary diary data has enabled the relationship between energy intake and physical capability to be explored, with positive results. Energy intakes decrease with age, and lack of total food intake is a major problem in the older population leading to frailty [25, 28]. The current results suggest that even in mid-life it is important to eat sufficient energy to ensure good muscle strength.

Results for protein are speculative but indicative of associations with physical capability measures. The current literature is conflicting on whether protein intake is associated with capability and on whether older people need more than current recommended amounts to maintain muscle mass and function. A recent task force report concluded that older people would be unable to utilise additional protein [29], and increased protein did not improve muscle function in frail nursing-home patients [30]. On the other hand, protein intake has been related to muscle mass and frailty in several longitudinal studies of older people [6, 7]. The findings in the current analysis that protein was related to grip strength before correction for energy but not when energy was included suggests effects of protein independent of energy intake, which would be the case if related to postprandial concentration of amino acids and muscle function, rather than through protein having a role related to energy metabolism. Further work should include investigations of quality and mode of consumption. A ‘pulse’ of protein may benefit older people, providing a higher peripheral concentration of amino acids to optimise uptake into muscle, a process less efficient in older people [31].

In summary, in NSHD, analysis of diet in relation to measures of physical capability indicates that higher energy intake across adulthood is modestly associated with stronger grip strength later in life. Protein intake may also influence physical capability measures, but more detailed analysis of types and manner of consumption are required. This work has the advantage of using data from a nationally representative longitudinal study with a detailed measurement of diet at multiple time points on a sizeable number of subjects of both sexes, three different objective measures of physical capability and information on a wide range of confounders collected prospectively.

Key points

- Energy intake was related to grip strength in longitudinal analyses.
- Evidence of relationship between protein intake in absolute terms (g/d) and grip strength and standing balance.
- Different measures of physical capability are influenced differently by diet.

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Scale, nature, preventability and causes of adverse events in hospitalised older patients

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Abstract

Objective: to gain insight into the scale, nature, preventability and causes of adverse events in hospitalised older patients.
Design: a three-stage retrospective, structured, medical record review study of 7,917 records of patients admitted in 21 Dutch hospitals in 2004.